High Reliability Gas Lift Flow Control Devices Increase Well Safety and Reduce Well Intervention Frequency

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Need for High Reliability Gas Lift Valves

- Regulatory requirement is much higher than other parts of world
- Subsea/TLP completion where the risk and the cost for intervention or to change failed reverse-flow valve are high
- Waterflood with seawater as a source commonly results in reservoir souring. Sour produced fluids must not be allowed into the casing annulus
- HSE case requires a zero-leak check valve
- Viable for any gas-lift well
Problems to Commonly Used Gas-lift Valves

- Standard gas lift hardware compromises the well integrity envelope
- The check valve/“check dart” is prone to failure due to high velocity flow cut and is not a reliable barrier
- It is common for the reverse-flow valve to leak at low pressure
- A gas lift mandrel with an open pocket allows flow from the tubing to the casing
Solution

• Protect the check valve sealing surfaces from exposure to high velocity fluids
  – Redesign the gas lift flow control device to use a flapper and flow tube

• Prevent flow of tubing contents into the casing annulus when the mandrel pocket is open
  – External mounted check valve
External Mounted Check Valve (FAST-TEC™)
Design and Qualification Procedures

- CFD (computational fluid dynamics) modelling as assessment, design and optimization tool
- Acceptance criteria
- Low pressure leakage tests (individual and dowhole sub-assembly system)
- Static and cyclic high pressure tests
- Explosive decompression test for elastomer used as seating o-ring material
- Fatigue performance tests for moving parts
- Erosion resistance tests with water
- Gas flow performance tests
- Field trials
The simulation scenarios were carefully considered and arranged to cover the worst case scenarios so that overall results can be supported by the reasonably high safety factor for confidence.

Based on the worst case scenarios evaluated by CFD, the acceptable leaking rate should be limited to 0.001 scf/D without imposing a H₂S critical threat to the casing.
Acceptance Criteria for High Reliability Gas Lift Valve

• The test criteria set by Shell safety case and evaluated by the CFD modeling requires every check valve hold pressure tight from 1 psi up to 8000 psi.

• Industrial standards for Acceptable leakage for gas lift
  – 35 SCF/D (1 SCM/D) gas leakage for gas lift devices (API API11V1)
  – 35 SCF/D (1 SCM/D) gas leak rate (ISO Standard 17078.2)
  – 1 bubble per minute (0.15cc/min) at 50 psi differential for Class VI control valve

• Almost all reverse-flow gas lift valves in the market do leak in a small amount at low pressure (1 to 15 psi)

• Critical challenge to HSE case where souring fluid is not allowed into the casing
Low Pressure Test Apparatus for HRC/HRO

- 2 HRC’s in horizontal
- Bubble Detectors
- Pressure Gauge
- Pressure Regulator
Leaking Behavior for Typical Reverse-flow Check

Leakage Testing with 1" Standard Gas Lift Orifice Valve with 1/8" Port

![Graph showing leak rate vs. pressure differential](image-url)
Low Pressure Reverse-Flow Sealing Performance

Testing with 10 samples with optimized design, 80% originally assembled HRCs are able to meet zero leakage at 1 psi. Only 2 out 10 checks did leak at 1 psi until 30~40 psi to seal.
High Pressure Static and Cyclic Tests

- High pressure static test
  - hold 8000 psig for 10 to 18 hours

- High pressure cyclic test
  - being cycled 15 times with 15 minute minimum hold times
  - no nibbling or visual damage of any sort on either of the o-rings
## O-ring Material ED Test

<table>
<thead>
<tr>
<th>Autoclave number</th>
<th>samples</th>
<th>Pressure (psi)</th>
<th>Temp (F)</th>
<th>Exposure (days)</th>
<th>Bleed rate (min)</th>
<th>Type gas phase</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 Chemraz 510</td>
<td>3500</td>
<td>170</td>
<td>6</td>
<td>14 min (250 psi/min)</td>
<td>Pentane; Methane with 5% CO2</td>
<td>No Blister/ Crack</td>
</tr>
<tr>
<td>2</td>
<td>2 Chemraz 510</td>
<td>3500</td>
<td>170</td>
<td>6</td>
<td>7 min (500 psi/min)</td>
<td></td>
<td>No Blister/ Crack</td>
</tr>
</tbody>
</table>
The max rate of HRO w/ 5/16" port is 118% higher than industry standard orifice valve.
The max rate of HRO w/16/64" port is 67% higher than industry standard orifice valve.
## HRC/ HRO Erosion Test Summary

<table>
<thead>
<tr>
<th>Test Samples</th>
<th>Test ΔP</th>
<th>Test Duration</th>
<th>Pumping Rate</th>
<th>Total Volume</th>
<th>Failure Criteria</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRC</td>
<td>1000 psi</td>
<td>7 days</td>
<td>80 gpm</td>
<td>18,000 bbls</td>
<td>Leak Rate &gt; 350 scf/D @ 100 psi diff</td>
<td>Good condition after 7 days test</td>
</tr>
<tr>
<td>1/8” port HRO</td>
<td>1000 psi</td>
<td>7 day (168 h)</td>
<td>10 gpm</td>
<td>2400 bbls</td>
<td></td>
<td>No erosion problem after 7 days</td>
</tr>
<tr>
<td>1/8” port standard orifice</td>
<td>1000 psi</td>
<td>1 day (24 h) to failure</td>
<td>10 gpm</td>
<td>343 bbls to failure</td>
<td></td>
<td>Severely eroded after 1 day’s flow</td>
</tr>
<tr>
<td>5/16” port standard orifice</td>
<td>1000 psi</td>
<td>7 day (168 h)</td>
<td>43~57 gpm</td>
<td>10,560 bbls</td>
<td></td>
<td>Slightly eroded after 6 days</td>
</tr>
</tbody>
</table>
1” HRO with 1/8” Port Erosion Test (7 day)

HRO w/ 1/8” after 7 days erosion test

Flapper of HRO w/ 1/8” with a slight mark caused by sliding of flow tube. The mark is inner side of flapper.

Good o-ring in HRO (1/8”)

HRO 1/8” flow tube and spring
1” Standard Gas Lift Orifice Erosion Test (1 day)
Comments and Conclusions

• Clear business case

• High reliability gas lift valves which use the flapper and the flow tube technology meet well safety case and reduce well intervention frequency.

• 80% high reliability check valves achieve bubble tight sealing at low pressure

• High reliability gas lift valves definitely outperform any standard gas lift valves in term of high velocity fluid cut resistance

• High reliability gas lift valve family perform very well in the flow capacity. The maximum gas flow rate for 1” HRO/HRC is averagely 10 ~100% higher than the 1” standard orifice valves given the same port and the pressure
Acknowledgment

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